THE TECHNICAL COOPERATION PROGRAM

SUBCOMMITTEE ON NON-ATOMIC MILITARY RESEARCH AND DEVELOPMENT

Data Replication in Low Bandwidth Wireless Military Environments

Workshop Report from TTCP C3I TP-10

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ABSTRACT (Maximum 200 words)

TTCP 3I Group Technical Panel 10 held a Workshop on "Data Replication in Low Bandwidth Wireless Military Environments" in the United States, at Fort Leavenworth, Kansas from 20-22 April 1999. The workshop addressed the problem of data replication among distributed databases using unreliable wireless communication links. With such links, the data in adjacent databases on the battlefield will not be fully consistent much of the time. One strong conclusion was that commercial database replication products are not yet up to the challenge on the tactical battlefield. There is a need for light-weight yet robust support for peer-to-peer replication designed to operate continuously over wireless broadcast communications media. Research in a number of areas is required. Database concepts need to evolve so rules for managing data can be seamlessly integrated with the data themselves.

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Executive Summary

TTCP C3I Group Technical Panel 10 held a Workshop on "Data Replication in Low Bandwidth Wireless Military Environments" in the United States, at Fort Leavenworth, Kansas from 20-22 April, 1999. The workshop had 52 participants, 41 from the United States, 9 from Canada, 1 from the United Kingdom and 1 from Australia. This report summarizes the results of that workshop.

The workshop addressed the problem of data replication among distributed databases using unreliable wireless communication links. With such links, the data in adjacent databases on the battlefield will not be fully consistent much of the time. The purpose of the workshop was to open lines of communication and exchange ideas as to how to use databases even when traditional consistency expectations are unrealistic.

One strong conclusion emerging from the workshop was that commercial database replication products are not yet up to the challenge on the tactical battlefield. The enterprise model driving replication solutions for major database vendors still appears to be a client-server model in which replication occurs between servers connected by high bandwidth links. This solution is not appropriate where nodes are linked by a radio system characterized by low and variable throughput and unreliable connectivity. There is a need for light-weight yet robust support for peer-to-peer replication designed to operate continuously over wireless broadcast communications media.

Mobility – the capability to disconnect and later reconnect and synchronize database content –was well addressed in several presentations, but in each case it was assumed that the wireless environment could handle the load to resynchronize. Several presentations mentioned "caching" of information before an expected disconnection to minimize large downloads upon reconnection.

Adaptivity – the ability to adapt information flow to changing network and battlefield conditions – has received little attention from DBMS vendors. To meet military needs, several capabilities must be included in replication mechanisms. First, network performance data must be available. Second, the data model must include a communications model so that there is a place to store and maintain network performance attributes. Third, there must be a way to make use of these data by the replication mechanism. Three encouraging signs in commercial database evolution were noted, namely emerging database vendor support for commercial, mobile users, an increasing trend to support replication between heterogeneous databases, and the availability to users of measured transaction delays in output queues.

To address the shortcomings noted above, research in a number of areas is required. Careful management of the information flow by both application and network layers is important to avoid an undisciplined, uncontrolled "push" of information to recipients. A key is a set of procedural rules that define who on the battlefield should receive a given piece of information together with a mechanism for implementing the rules. Database triggers, middleware, and intelligent agents offer possible mechanisms. Database concepts need to evolve so that rules for managing the data can be seamlessly integrated with the data themselves. To fully exploit bandwidth-efficient information exchange via replication of database transactions, conceptual database schema must be developed which reflect accurately and completely the set of entities and relationships found on the battlefield. Methods need to be developed for

simulating and measuring the impact of information management strategies before their integration into fielded tactical command and control systems.

For directory- and file-based replication systems, significant improvements would be obtained if only changes in files, rather than complete files, could be replicated. For such systems, more attention needs to be devoted to reducing latency. For data (transaction-level) replication systems, database resynchronization upon reconnection and managing database inconsistency when bandwidth prevents full resynchronization are important issues. Minimizing uncertainty while disconnected through use of predictive algorithms deserves attention. Commercial relational databases need to evolve to support selective replication of just those fields within a table row that have changed rather than the entire row. Finally, the database products need to make network performance data available to the application, the database schema in the application must include a place to store and maintain these network performance attributes, and the replication mechanism must be able to exploit these data.

Contents

1. Introduction

A workshop on the subject of "Data Replication in Low Bandwidth Wireless Military Environments" was held at Fort Leavenworth, Kansas from 20–22 April 1999. The workshop, organized under the auspices of TTCP C3I Group Technical Panel 10 (TP 10) on Distributed Information Systems, had 52 participants, 41 from the United States, 9 from Canada, 1 from the United Kingdom and 1 from Australia.

A list of presentations is attached at Annex A[1] and an attendee list at Annex B.

The workshop addressed the problem of data replication among distributed databases using unreliable wireless communication links. With present-day radio technology, such links are characterized by extremely limited data throughput. For the foreseeable future, tactical data communications supporting digital tactical command and control networks are unlikely to be able to distribute all of the timely information required to support global situation awareness. A necessary corollary is that the data in adjacent databases on the battlefield will not be fully consistent much of the time.

The purpose of the workshop was to open lines of communication and exchange ideas as to how to use databases even when traditional consistency expectations are unrealistic. In other words, managing inconsistency may begin by accepting inconsistency. There are many ways to approach this problem, and the goal was to get both military and scientific personnel together to discuss the many aspects of this technology area.

To encourage free exchange of ideas and information, the first two days of this unclassified workshop were organized as an open session. Information presented was considered to be in the public domain, as if it had been presented at an open scientific conference. The morning of the third day was a 'lessons learned' session involving TP 10 members only.

Two questions were posed to participants as themes for the workshop by the organizers during the introductory remarks:

(1) We have been told "Don't worry, industry will solve the problem". To what extent is this true?

(2) Is the military a niche market in low bandwidth data replication?

Workshop results are organized under these two themes in Sections 2 and 3 respectively. Section 4 summarizes future research directions. Section 5 mentions several technologies which, although beyond the scope of the workshop, have the potential to influence how the data replication problem on the tactical battlefield will be approached in the future. Section 6 presents concluding remarks.

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1 To access the presentations see http://www.dtic.mil/ttcp/.

Question 1: We have been told "Don't worry, industry will solve the problem". To what extent is this true?

1.1 File Replication

The field of replication has two domains: file replication and database replication. Most commercial products address one of these two, but not both. Although the workshop's primary interest was in database replication (or mechanisms that operate at the transaction resolution) file replication is also a major concern for the military, especially within command posts.

Among commercial file replication systems, Starburst's Omnicast product, which exploits Starburst's highly scalable reliable multicast protocol (Multicast-File Transfer Protocol, MFTP), is one product that supports efficient one-to-many and many-to-many file distribution to large numbers (thousands) of users using a multicast file transfer protocol. It has been tested favorably against a reliable unicast protocol (TCP) over tactical radio nets. Such products optimize number of users and reliability at the expense of latency (transmission delay). They are still not applicable in situations where latency is an important driver.

1.2 'Wireless' vs 'Mobility'

The terms 'wireless' and 'mobility' are sometimes used interchangeably in industry as if they referred to the same problem – obviously, they do not. Often, it is mobility – the capability to disconnect and later re-connect and synchronize – that is the focus of the "wireless" features described. Because this is a common occurrence in a wireless environment, mobile and wireless environmental characteristics are sometimes confounded. The disconnect/reconnect problem was well addressed in several presentations, but this is only a part of the wireless and/or low bandwidth problem. In the cases presented, it was assumed that the wireless (or other communications) environment could handle the load to resynchronize. On the tactical battlefield, this assumption is frequently invalid (see following section). Several of the projects mentioned "caching", a term which refers to the attempt to load what one needs in advance of an expected disconnection to minimize the need to download large data items at a later time. This is applicable to both file and transaction (database) replication approaches.

1.3 Enterprise Models – Commercial vs Military

The enterprise model driving replication solutions for major database vendors still appears to be the client-server model. In this model, servers replicate data over high bandwidth links (typically Ethernet) using tight-consistency protocols such as two-phase commit while remote workers (clients) communicate with an enterprise server using wired or wireless links to upload/download information. In each case, disconnected operation is supported. However, the underlying assumption is that, upon reconnection, either the communications 'pipe' is wide enough to support rapid resynchronization, or (in the case of low bandwidth wireless connections) latency is not an issue so the reconnected client can take as much time as required to resynchronize its database with the server. The military tactical battlefield problem is not adequately addressed by the above enterprise model because: (1) low bandwidth wireless communications using a broadcast protocol is the only option, (2) continuous peer-to-peer replication is required to preserve operational autonomy of nodes, (3) disconnection is frequent and usually unplanned, and (4) latency is almost always an

issue. When database vendors refer to peer-to-peer replication, they are referring to server-to-server replication, usually over a high bandwidth (or at least reliable low-bandwidth) link. In principle, server software could be installed at each battlefield node. However, server software tends to be costly and demanding of system resources, making this an unattractive option for deployment in large numbers on assets with limited computing resources (the norm on the tactical battlefield). There is a need for light-weight yet robust support for peer-to-peer replication designed to operate continuously over wireless broadcast communications media.

Some relational database management system (RDBMS) vendors still tend to support row-based rather than transaction-based replication. In row-based replication, whole rows of relational tables are replicated, even though many of the fields in the row have not changed value. A more selective approach, in which replication of individual transactions (fields) is supported, could significantly reduce the quantity of information required for transmission.

1.4 Adaptivity

Adaptivity (the ability to adapt information flow to changing network and battlefield conditions) has received little attention from DBMS vendors. A prerequisite to this feature is the ability to acquire network performance data and no system currently supports this requirement. This is due in part to the lack of support from the network management community to provide this information. Some products let the user dictate what percent of the communications asset may be used for replication. However, one vendor (Sybase) measures transaction delay in the output queues and (they state) make these data available to the user applications. This is a major step in the right direction.

To meet military needs, several capabilities must be included in replication mechanisms. First, as noted above, network performance data must be available (in particular, average session delay and average session throughput). Second, the data model must include a communications model so that there is a place to store and maintain network performance attributes. Third, there must be a way to make use of these data by the replication mechanism. For example, if triggers are used to control/invoke replication, then a robust language must exist to describe the real-time calculations required to tune the replication mechanism to current network performance. Research topics that address these issues are still of vital importance to military users and are required before database technology can be of significant use to the lower echelons that are connected with combat net radios.

1.5 Encouraging Signs

Three encouraging signs in commercial database evolution are worthy of note. First is emerging database vendor support for commercial, mobile users (e.g. Sybase's Ultralight, a product that is supposed to provide the functionality and reliability of an SQL RDBMS in an extremely small footprint (approximately 50K), and to support bi-directional wireless synchronization with a central RDBMS). Second is an increasing trend to support replication between heterogeneous databases. Third, as noted above, is the availability to users of measured transaction delays in output queues.

2. Question 2: Is the military a niche market in low bandwidth replication?

The answer remains yes, but to a lesser extent than in the past. There is still a need for emphasis on providing an interface between the information management and the network management communities. Once this is established, strategies and algorithms must be produced to determine how to make the best use of the current network capabilities. This will require military science as well as computer science research. Often, it comes down to deciding what information is the most critical. There is no simple heuristic to determine this, so it must be inferred from the perceived state of the battlefield as represented by the information in the local database.

3. Future Research Directions

The workshop provided encouraging signs that research is being carried out relevant to the topic of data replication in low bandwidth environments. A variety of approaches is being investigated. It was clear that the problem is multi-faceted and no single approach will provide all the answers. The two sections which follow identify research directions that are relevant to the military environment.

3.1 Procedurally-Based Information Management Techniques

The essential purpose of managed data replication in a low bandwidth military environment is the intelligent selection of information to share. The low bandwidth constraint means that a constant, undisciplined, uncontrolled "push" of information is not supportable by the communication system. The constraint places a premium on careful management of information flow, both by application and network layers.

A key to information management in a low bandwidth environment is a set of **procedural rules** that define who on the battlefield should receive a given piece of information for a given situation. The military user (subject matter expert) must establish these rules that must, ultimately, be defined in a form suitable for automated application in a command and control system. The concept of **triggers** employed in active databases provides a promising mechanism for the implementation of such rules and should be exploited further. However, the long term goal should be to **rethink database concepts** to move toward a model which unifies application logic and data storage into a single environment. In other words, rules for managing the data (including dissemination rules) should be seamlessly integrated with the data itself. In a low bandwidth context, the challenge is to achieve this goal while minimizing the quantity of management data that must be transmitted with a data element when it is replicated. A key component of this approach is to stop thinking of the database as a repository for fields of structured military messages and to start thinking of it (and its underlying data model) as a repository for a dynamic model of the battlefield (**model-based approach**).

Another concept worth exploring is a **cost-based approach** to information dissemination, i.e. assessing the communications "cost" of sending the information immediately and comparing it to the operational "cost" of not sending the information immediately as a basis for controlling the information flow [presentation by Wolfson]. A key issue here is the basis for assigning a numeric cost to each factor.

Attention should be paid to methods for **simulating and measuring the impact** of proposed information management techniques and data replication strategies before integrating them into fielded systems. Commercial products permit measurement of transmission delay (latency), but latency alone will not reveal whether mission-critical information arrived on time or if serious information gaps are developing in a local situation picture. Tools are required for real-time monitoring of data consistency across replicated databases for selected data elements. This unique military requirement is not well addressed by database vendors, network suppliers, or the simulation community.

3.2 Data and File Replication

For **directory- and file-based replication systems**, it will be necessary to minimize the amount of information exchanged when synchronizing directories on different machines. Presently complete files are transferred. If only changes in the files were transferred, then

significant improvements would be obtained [presentation by O'Brien]. Also, systems that focus on scalability and reliability at the expense of latency should pay more attention to reduced latency as a design driver.

For data (transaction-level) replication systems, an important topic is **database resynchronization upon reconnection**. In this context, a major concern is **conflict resolution**. A conflict occurs when two users independently update the same data element in their local databases while disconnected, the values are not the same, and the replication process tries to reconcile the values when the databases are reconnected. Conflict resolution can demand considerable effort (and bandwidth) if user intervention is required. Automated conflict resolution schemes that minimize communication demands warrant investigation. The role of different data ownership schemes in **conflict avoidance** is also an interesting research issue. Another major issue is **managing database inconsistency** in the situation where bandwidth and/or operational constraints prevent a database from re-synchronizing completely upon reconnection. By applying military science principles and expertise to the problem, consistency requirements may be relaxed to more realistic values, thus significantly reducing the number of resynchronization transactions required between different databases.

A second important topic is **minimizing uncertainty while disconnected** through use of **predictive** algorithms. By exploiting information already in the database, such as last reported vehicle speed and direction, new values for other database elements may be derived via prediction (e.g., dead reckoning). Even better approximations can be achieved if planned route information is exchanged so that waypoints can be used to further reduce errors via prediction and define realistic reporting thresholds.

Most of the **dynamic relationships between data replicas** presently supported by COTS relational database products are limited to table rows. This requires exchange of data fields within the rows that may not have changed. If the dynamic relationships could extend only to modified fields (i.e., selective replication) then a significant decrease in the quantity of information to be transferred would be obtained.

To properly control information flow, the command and control nodes require continuous knowledge of **network performance data**, in particular, average session delay and average session throughput. More database vendors should follow Sybase' lead in measuring transaction delay in its output queues and making this information available to users. The data model must include a communications model so that there is a place to store and maintain network performance attributes. Third, there must be a way to make use of these data by the replication mechanism and trigger language semantics.

4. Impact of New Technologies

Most of the presentations at the workshop dealt with replication of data among conventional databases residing in the application layer (command and control nodes). Conventional database technology is mature and well entrenched in the marketplace (particularly relational technology). Defense systems, increasingly based on COTS technologies, will employ commercial database management systems to manage and control replication of data for the near future. Several other technologies have the ability to influence, either directly or indirectly, how data replication will be carried out on the future tactical battlefield. They are noted below. A detailed consideration of their impact, however, was beyond the scope of the workshop.

Middleware (CORBA, DCOM), inserted between the application layer and conventional network layers, is based on distributed object technology and provides a set of services which can be very useful for transparently managing information flow in a distributed system (Reference 1). However, current versions of CORBA and DCOM require a level of communication overhead to support those services which is unacceptable in the very low bandwidth regime (less than 1 kbit/second) dealt with in this workshop. The Object Management Group that champions CORBA is studying this issue.

Software agent technology may offer a new tool for managing database consistency. Intelligent agents installed on remote nodes may discover information of interest to a client node and request that this information be broadcast to the client node (and all other listening nodes). With this approach, only data known to be of interest to at least one node is replicated. The approach supports the intelligent selection of information to share and has the potential to reduce bandwidth requirements by limiting the quantity of data transmitted.

The use of middleware and intelligent agents will permit flexibility in the way AI can be applied to the problem, by removing the requirement that the intelligence be tightly integrated with the data store.

Other technologies which can influence (directly or indirectly) data replication on the future tactical battlefield include those which can improve connectivity for distributed wireless nodes (satellite communications, cellular technology, airborne relays), improve data communications capacity (high capacity digital radios, asynchronous transfer mode (ATM)), and improve portable computer performance and capacity (personal digital assistants, palmtops, etc.). For more information on the communications technologies, the reader is referred to Reference 2.

5. Conclusion

This workshop was very successful in bringing together colleagues and collaborators in this rather specialized research domain. Government personnel (civilian and military) and government contractors, database vendors and members of the academic community attended, providing a good mix of government, industry and academic perspectives. The database vendors presented their approach to data replication. In return, they were sensitized to the military-specific aspects of data replication that were not well supported by their products. All parties left with a heightened awareness of the research challenges posed by the need to replicate data in a low bandwidth wireless military environment.

The workshop did not greatly change the direction of military research, but did provide optimism that industry is beginning to understand the problems encountered in the military environment.

6. Acknowledgements

The authors would like to express their thanks to all workshop participants, both for the excellent quality of their presentations and for their enthusiastic participation in the discussions. We would like to acknowledge Colonel James Bessler, the director of the TRADOC Program Integration Office for Army Battle Command System (TPIO-ABCS) at Fort Leavenworth for his interest in, and support of, the workshop and for providing Grant Auditorium as the Workshop venue. Finally, a special vote of thanks is due to two members of his staff, Major Larry Raville and Major Mike Boller, for their effective organizational and administrative work both prior to and during the workshop. The workshop ran very smoothly, thanks in no small part to their efforts.

7. References

1. Anderson, L., Chamberlain, S., Dorion, E., Defranco, C., Laws, J., Macleod, I., Rathmell, T., and Robinson, J.. TTCP C3I Group TP-10 Workshop Report on "The Requirements for Middleware to Support C3 on the Move", July 1999.

2. Andrews, P., Arnold, J.W., Boucher, Luc, Braddock, P.W., Evanowsky, J. B., Halloran, F., Hearn, D., Laws, J., Lorenzo, G., Nourry, G.R., Scaffidi, V., Swanson, R., Tenne-Sens, A., Thorlby, P. and Wagner, L.. "Emerging Communications Technologies and their Potential Applications in Future Military Communication Systems", Report of TTCP Subgroup S (C3I Systems) Technical Panel 8 on Networking and Communication Technology, Autumn 1996.

Annex A – List of Presentations

Tuesday, 20 April 1999

Title	Speaker	Company / Organization
Resilient Replication Mechanisms	Dr. Sam Chamberlain	US Army Research Lab.
The CODA File System	Prof. Mahadev Satyanarayanan	Carnegie-Mellon University.
BENGAL	Mr. Todd Ekenstam	Platinum Technology, Inc.
Tactical Information Exchange Requirements	Major R.K. Ferguson	Canadian Forces LO/Fort Gordon
Tracking Moving Objects	Prof. Ouri Wolfson	University of Illinois - Chicago
Testbed for the Evaluation of Battlefield Information Management Techniques Applied to a Low Bandwidth Tactical Wireless Communications Environment	Dr. Allan. Gibb & Jean-Claude St-Jacques	Defence Research Establishment Valcartier, CA
Informix Enterprise Replication	*Mr. Madison Pruet*	*Informix, Inc.*
Experiences from MCS	Mr. Joe Gilchrist	Lockheed-Martin
Data Consistency Issues in Support for Deployed Headquarters	Dr. Iain Macleod	Defence Science & Tech Org. C3 Research Centre
The TRIERARCH Trigger Architecture - Practice and Experience with Java and Other COTS Technologies	Mr. Richard Rabbat	Mass. Inst. Of Technology

Wednesday, 21 April 1999

Title	Speaker	Company / Organization
Next Generation Command and Control: Introducing the Artillery Regimental Data System (ARDS/ADM)	Mr. Michael Jones	MacDonald-Dettweiler
Replication and Reconciliation in Mobile Wireless Databases	Prof. B. R. Badrinath	Rutgers University.
Starburst Omnicast Concepts and Multicast FTP	Mr. Richard O'Brien	Starburst, Inc.
Data Streamlining	Major R.K. Ferguson	Canadian Forces LO/Fort Gordon
Model-Based Battle Command and Change Propagation in Advanced Database Systems	Mr. Gautam Thacker	Lockheed-Martin Advanced Technology Lab
Technical Concepts for the ATCCIS Data Replication Mechanism	Mr. Tony Antonello	Sybase, Inc.
Sybase Strategies for the Replication and Synchronization of Data	Mr. Tony Antonello	Sybase, Inc.
Middleware Issues for Low Bandwidth, Mobile Wireless Environments	Dr. Ravi Jain	Telcordia Technology
Situation Awareness System for Canada	Mr. Andrew Hill	Computing Devices, CA
The Joint Common Database Replication System	Mr. Bob Carneval	US Army Program Executive Office for C3 Systems

Annex B – List of Attendees

Speakers	Company / Organization
Dr. Sam Chamberlain	US ARL
Prof. Mahadev Satyanarayanan	Carnegie-Mellon University.
Mr. Todd Ekenstam	Platinum Technology
MAJ R.K. Ferguson	Canadian Forces LO, Ft Gordon
Prof Ouri Wolfson	University of Illinois - Chicago
Dr. A. Gibb	DREV
Mr. J.C. St-Jacques	DREV
Mr. Madison Pruet	Informix
Mr. Joe Gilchrist	PM-MCS
Dr. Iain Macleod	DSTO C3 Research Centre
Mr. Richard Rabbat	MIT
Mr. Michael Jones	MacDonald-Dettweiler
Prof. B. R. Badrinath	Rutgers Univ.
Mr. Richard O'Brien	StarBurst, Inc
Mr. Gautam Thaker	Lockheed-Martin ATL
Mr. Tony Antonello	Sybase, Inc
Dr. Ravi Jain	Telcordia Technology
Mr. Andrew Hill	Computing Devices, CA
Mr. Bob Carnevale	US Army PEO-C3S
Attendees	**Company/Organization**
COL James Bessler	TPIO-ABCS
MAJ Lawrence Raville	TPIO-ABCS
MAJ Mike Boller	TPIO-ABCS
Mr. Rich Silva	TSM CSSCS
Mr. Mark Poernbacher	MacDonald Dettweiler
Mr. John Benton	UMD
Mr. Les Anderson	SPAWAR Systems Center.
Mr. Cyril Pedrano	SPAWAR Systems Center.
Mr. Carl DeFranco	AFRL
Mr. Tony Hauschild	GCCS-A
Mr. Dave Vincent	MCS
Mr. Mike Swehla	Sun Tek Systems
Mr. John Raletz	TSM MCS
Mr. Venis Knight	Lockheed-Martin Company
LTC Campbell	Canadian Forces LO, Ft Leavenworth

Attendees (continued)	Company/Organization
MAJ Eric Hermansen	NDHQ Canada
Ms. Maria Lopez	ARL
Mr. George Hartwig	ARL
Mr. John McCray	Marconi
Mr. John Laws	DERA MOD
Dr. Steve Levy	Platinum Technology
Mr. Karl Beckett	PM-MCS
Mr. Rick Wallace	PM-MCS
Mr. Mohamed Meshal	PM ATCCS
MAJ Tom Dodd	TSM MCS
Mr. Paul Kohl	Sybase
Mr. Mark Chernoff	Sybase
Mr. Bruce Stults	Chameleon Search & Consulting.
Mr. Gerald Soltis	LOGICON
Mr. Leo McNeill	MITRE
Mr. Mike Preddy	SunTek Systems

Annex C – Glossary

Terms:

AI - Artificial Intelligence
ATCCS - U.S. Army Tactical Command & Control System
ATM - Asynchronous Transfer Mode
C3I - Command, Control, Communications and Intelligence
CORBA - Common Object Request Broker Architecture
COTS - Commercial Off-the-Shelf
CSSCS - Combat Service Support Control System
DBMS - Database Management System
DCOM - Distributed Component Object Model
GCCS-A - U.S. Global Command & Control System - Army
LO - Liaison Officer
MCS - U.S. Maneuver Control System
MFTP - Multicast File Transfer Protocol
RDBMS - Relational DBMS
SQL - Structured Query Language
TCP - Transfer Control Protocol

Organizations:

AFRL - U.S. Air Force Research Laboratory
ARL - U.S. Army Research Laboratory
DERA - U.K. Defence Evaluation & Research Agency (Ministry of Defence)
DREV - Canadian Defence Research Establishment Valcartier
DSTO - Australian Defence Science and Technology Organisation
MIT - Massachusetts Institute of Technology
NDHQ - National Defence Headquarters
PM - Project Manager
PEO-C3S - Program Executive Office – Command, Control, & Communication Systems
SPAWAR - U.S. Navy Space and Naval Warfare
TP-10 - TTCP, C3I Group, Technical Panel 10 - Distributed Information Systems
TPIO-ABCS - TRADOC Program Integration Office for Army Battle Command System
TRADOC - U.S. Army Training and Doctrine Command
TSM - TRADOC System Manager
TTCP - The Technical Cooperation Program
UMD - University of Maryland

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